United States Patent [19]

Burandt

[11] **4,438,737**

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[54] APPARATUS AND METHOD FOR CONTROLLING THE VALVE OPERATION OF AN INTERNAL COMBUSTION ENGINE

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[51] **Int. Cl.**³ **F01L 1/34**

[52] **U.S. Cl.** **123/90.17**; 123/90.31; 123/90.44

[58] **Field of Search** 123/90.15, 90.16, 90.17, 123/90.18, 90.27, 90.31, 90.39, 90.44

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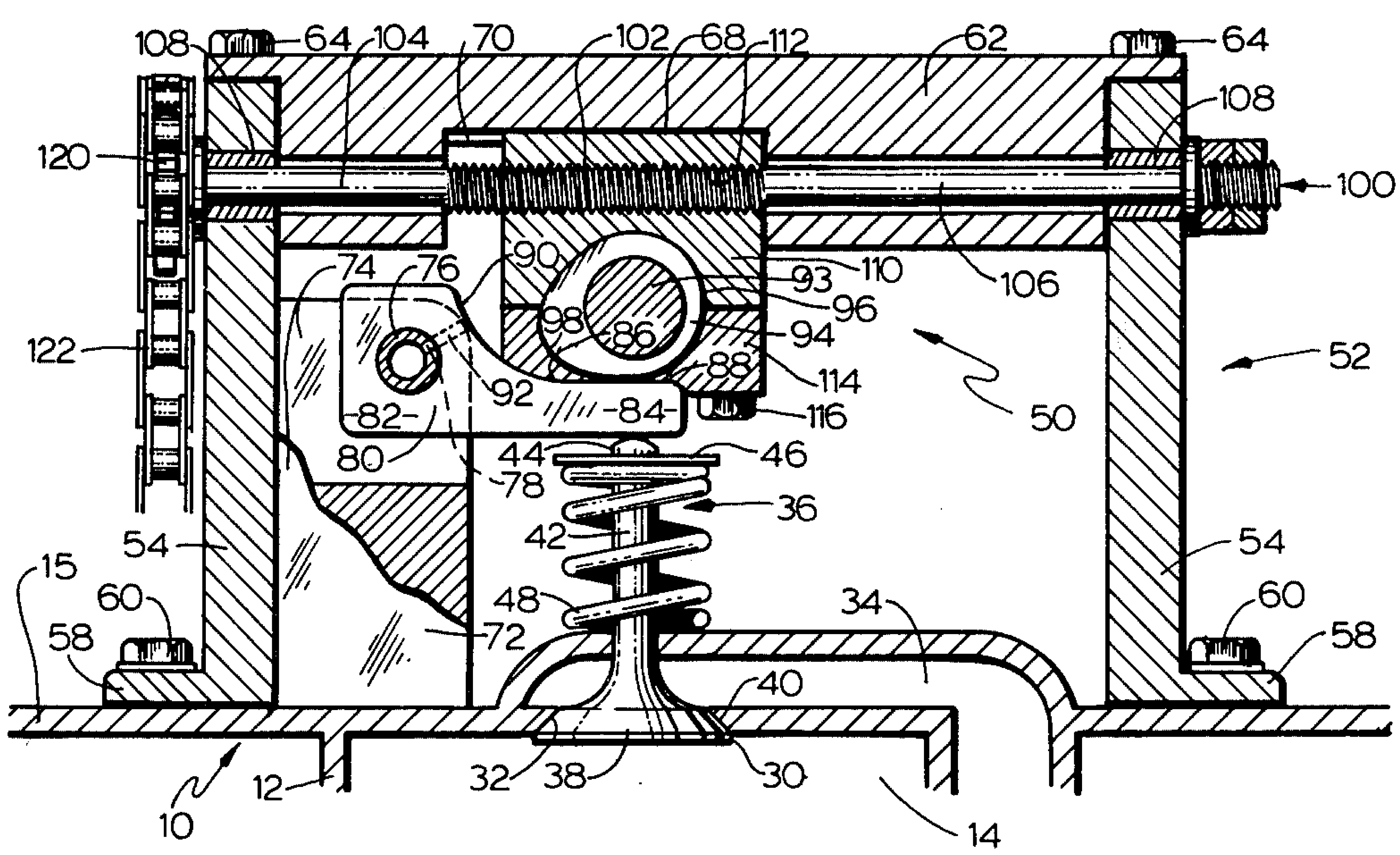
[57] **ABSTRACT**

A rotatable cam and pivotally mounted rocker arm are employed for each valve of an internal combustion engine. The rocker arm has a working or cam follower surface thereon which includes a straight section and a curved section. By relatively moving the cam and rocker arm so that the cam acts against appropriate portions of the cam follower surface, the moment of valve opening and closing is controlled, as well as the lift and duration of valve opening. The invention makes possible what is herein termed a five-cycle operation in that the following sequence can be achieved: (1) intake, (2) decompression, (3) compression, (4) power, and (5) exhaust.

17 Claims, 13 Drawing Figures



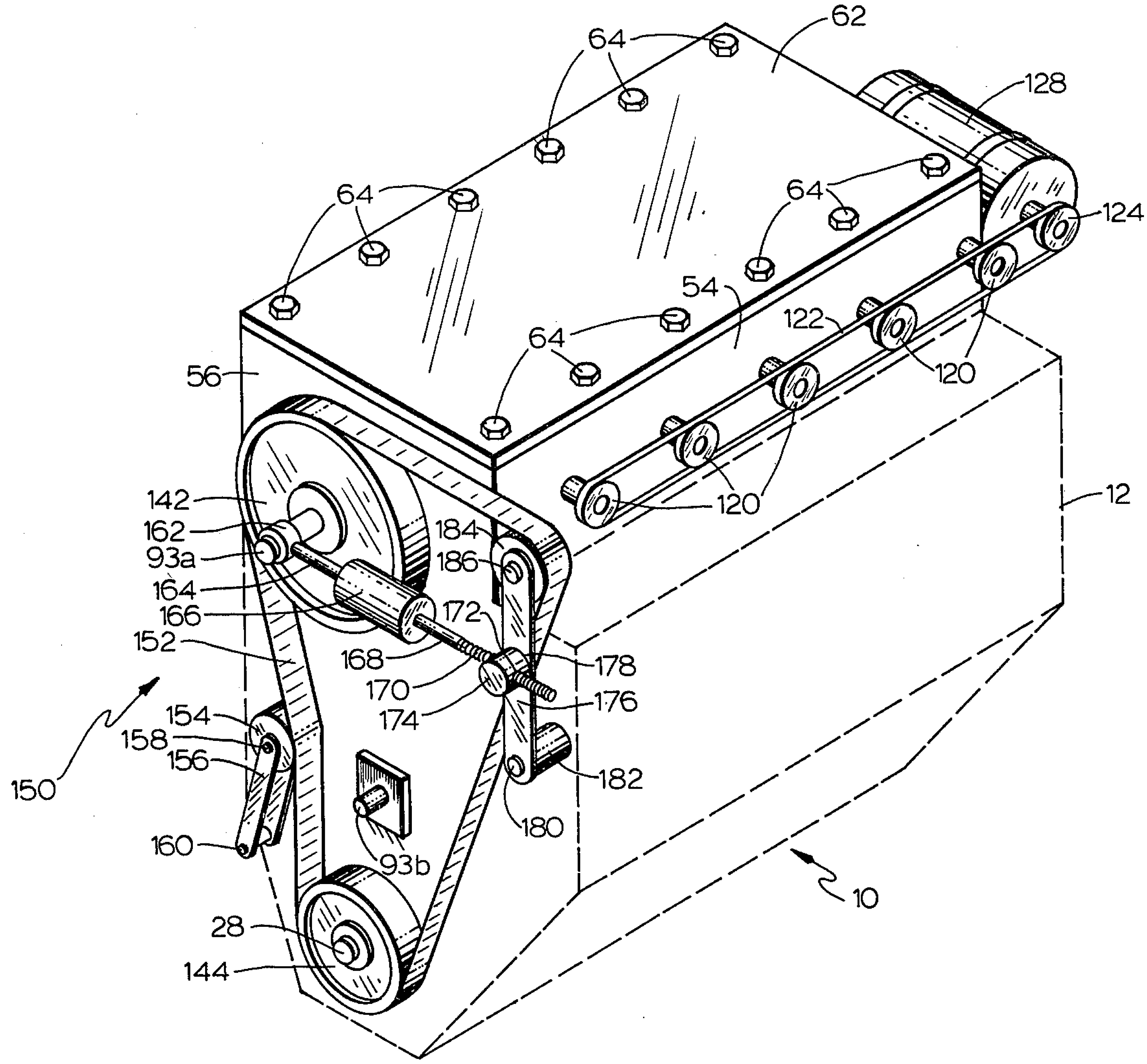

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FIG. 1

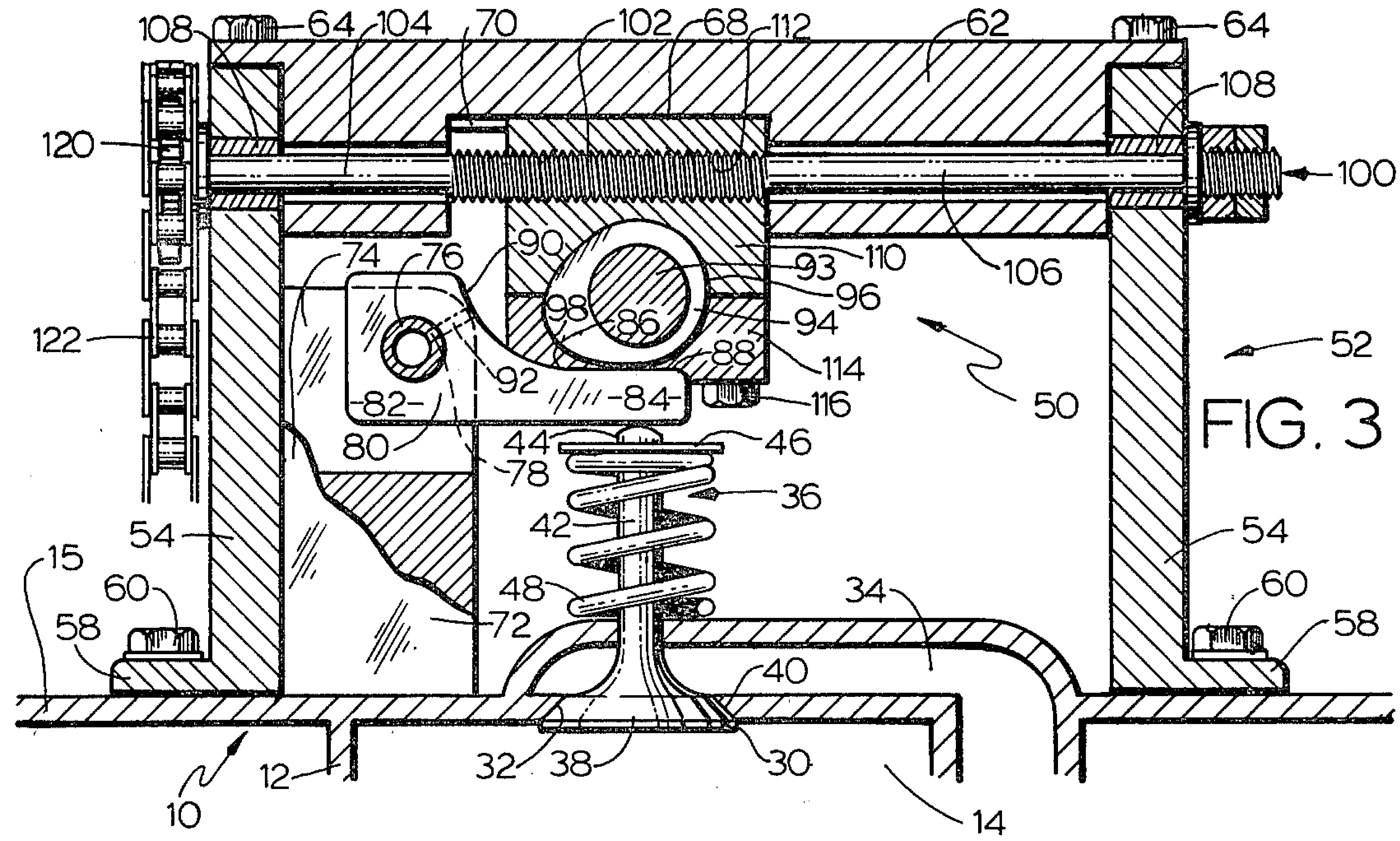

FIG. 3

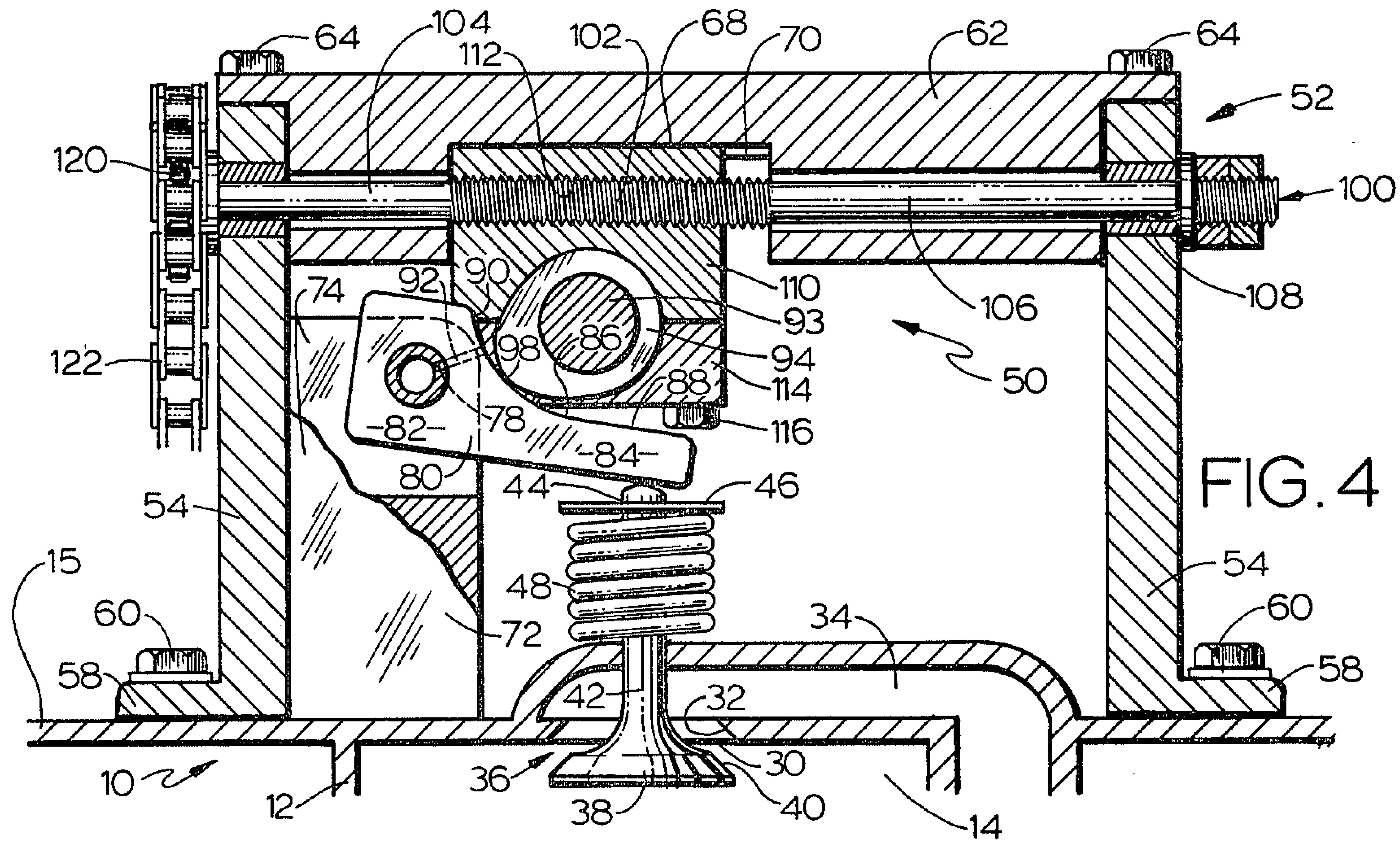

FIG. 4

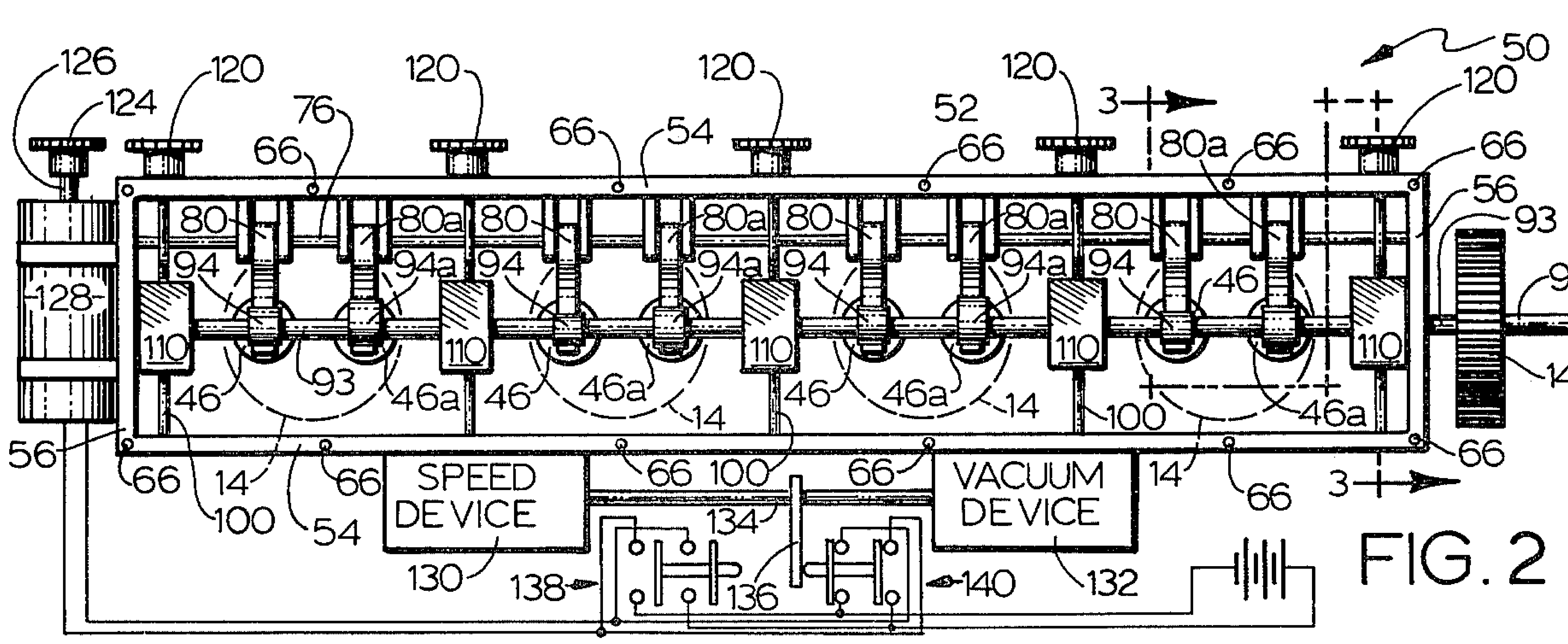

FIG. 2

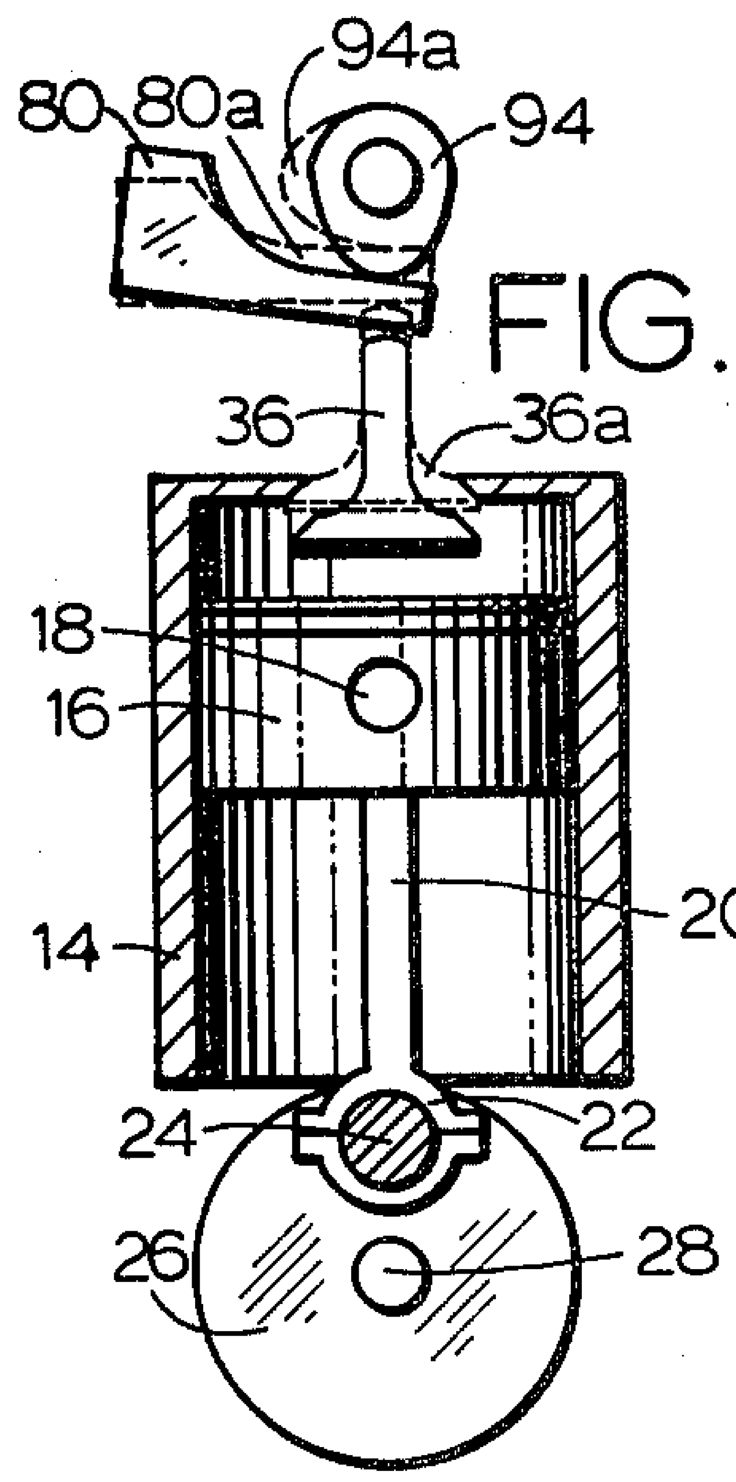

FIG. 5

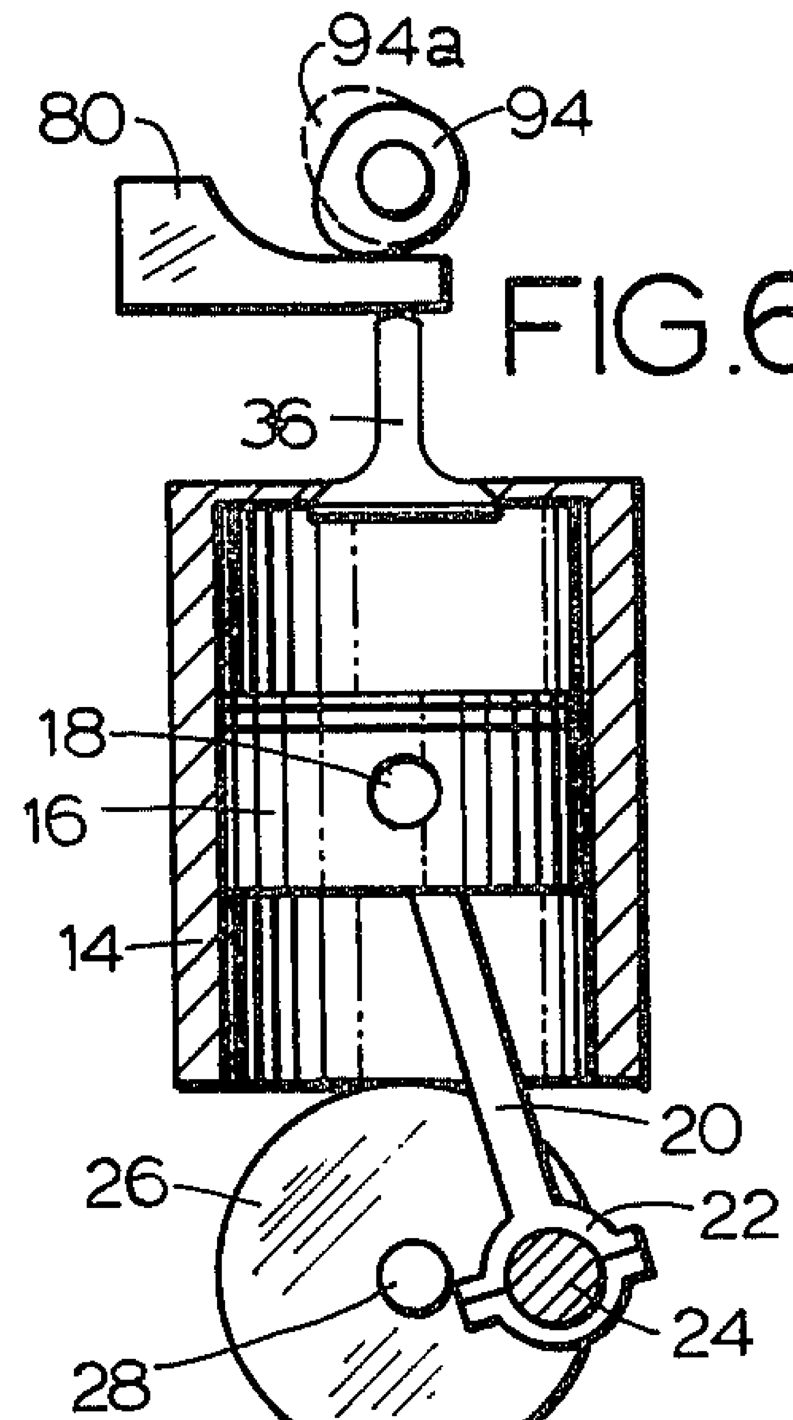

FIG. 6

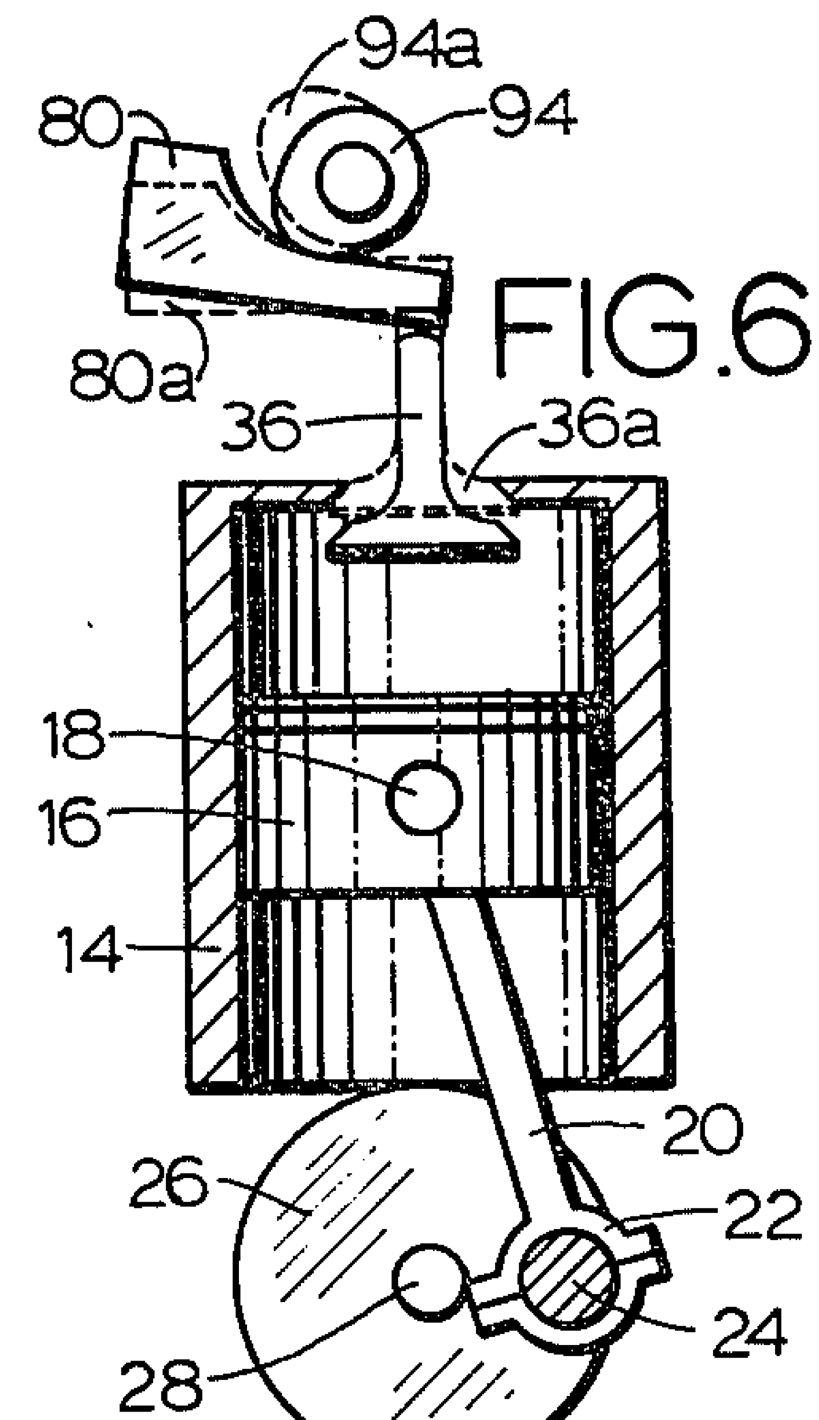

FIG. 6A

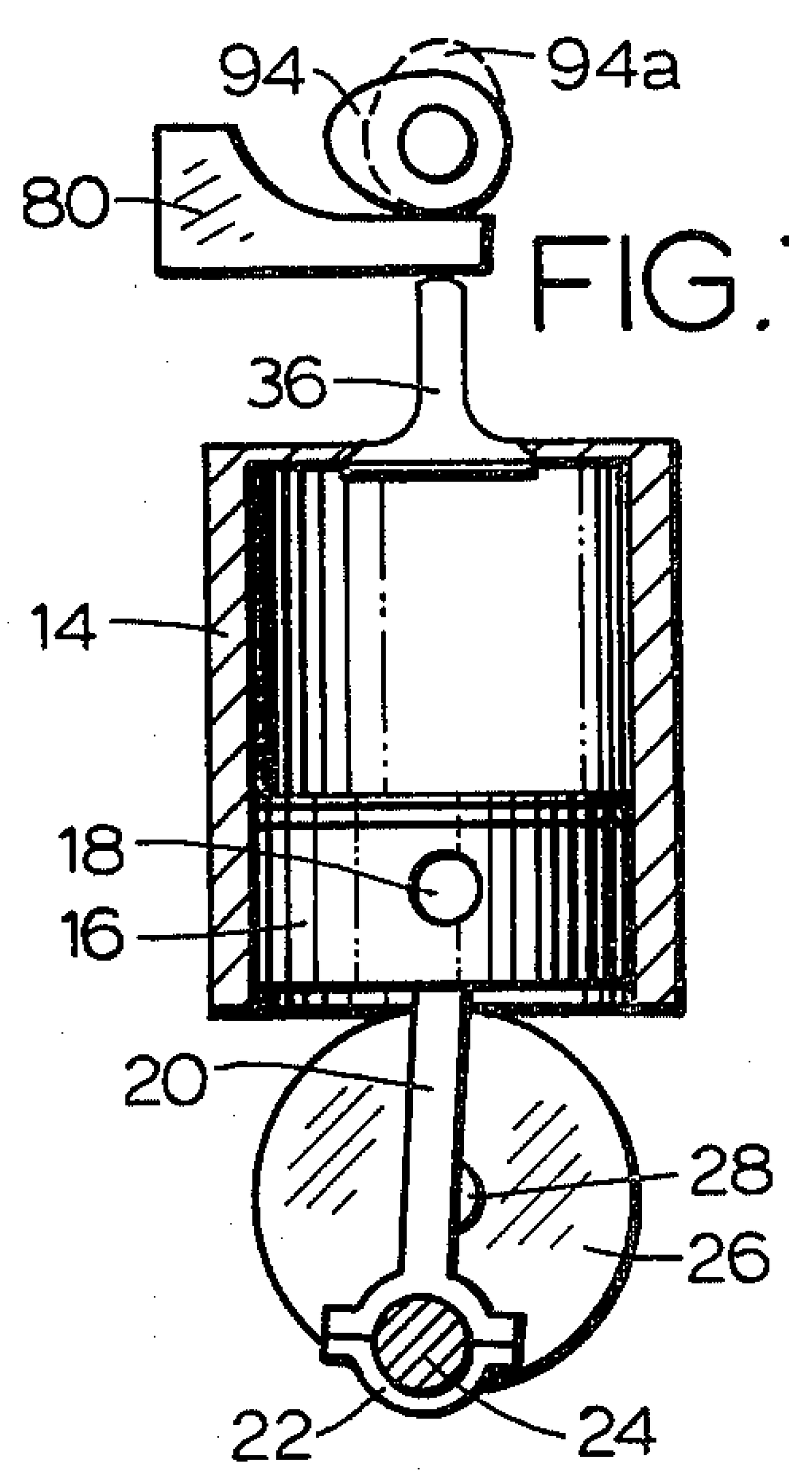

FIG. 7

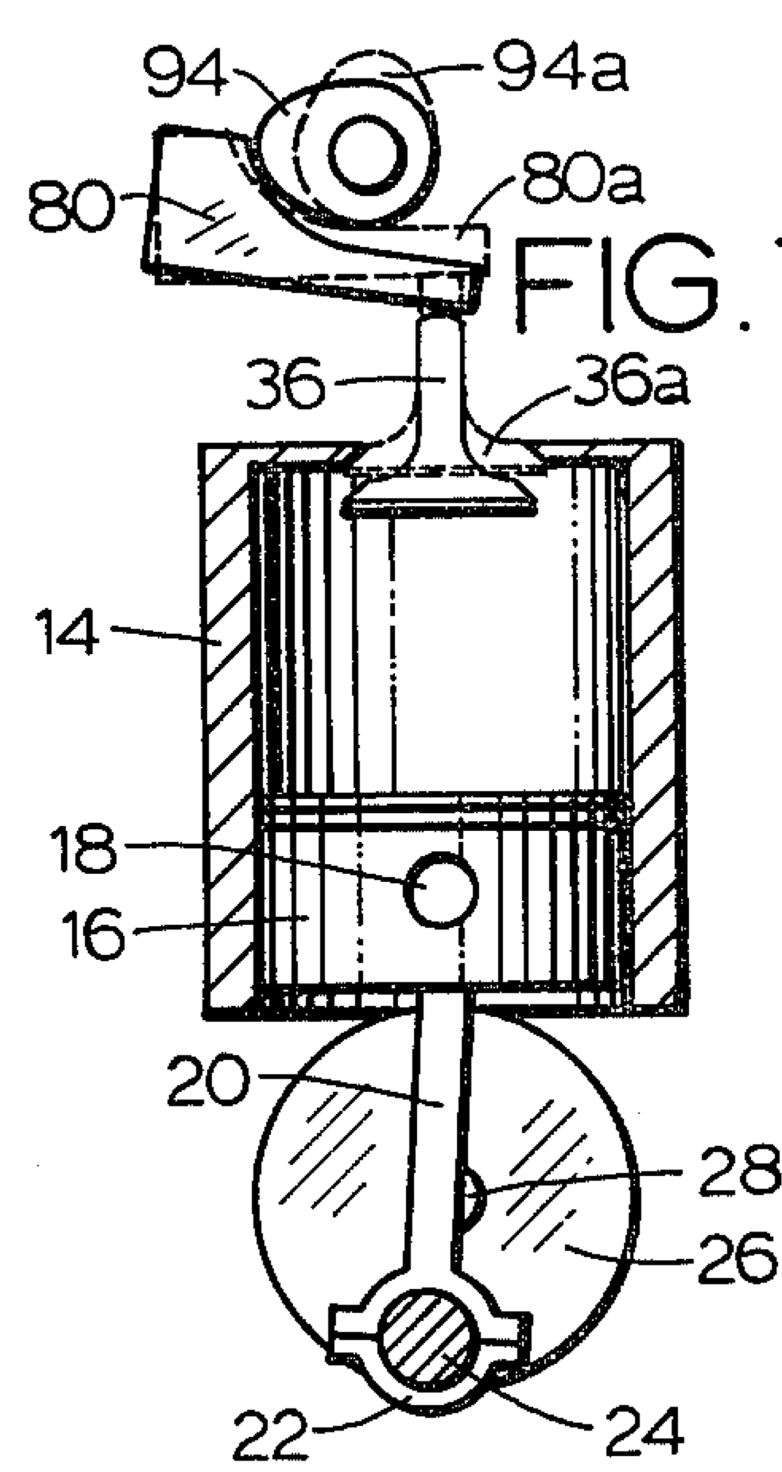

FIG. 7A

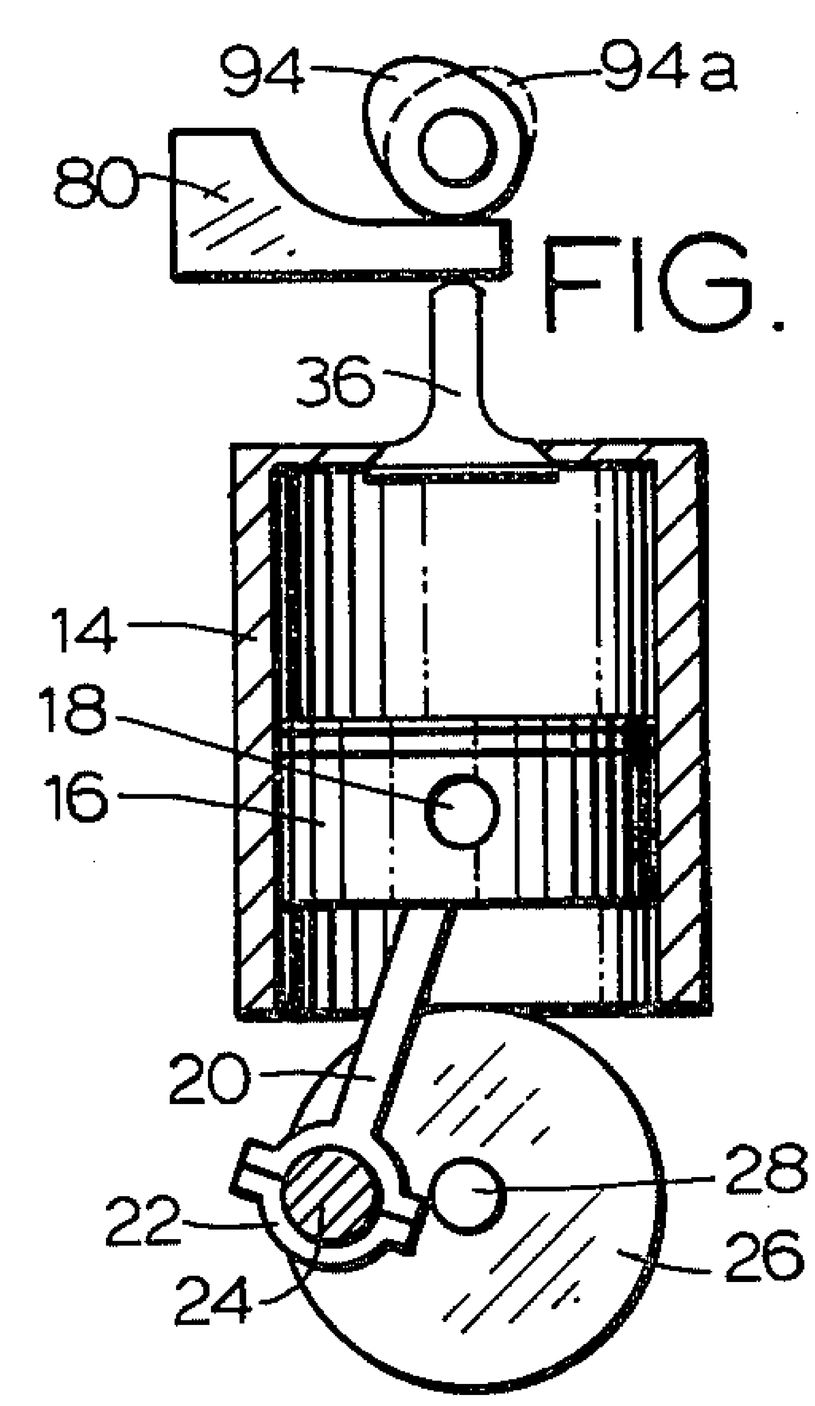

FIG. 8

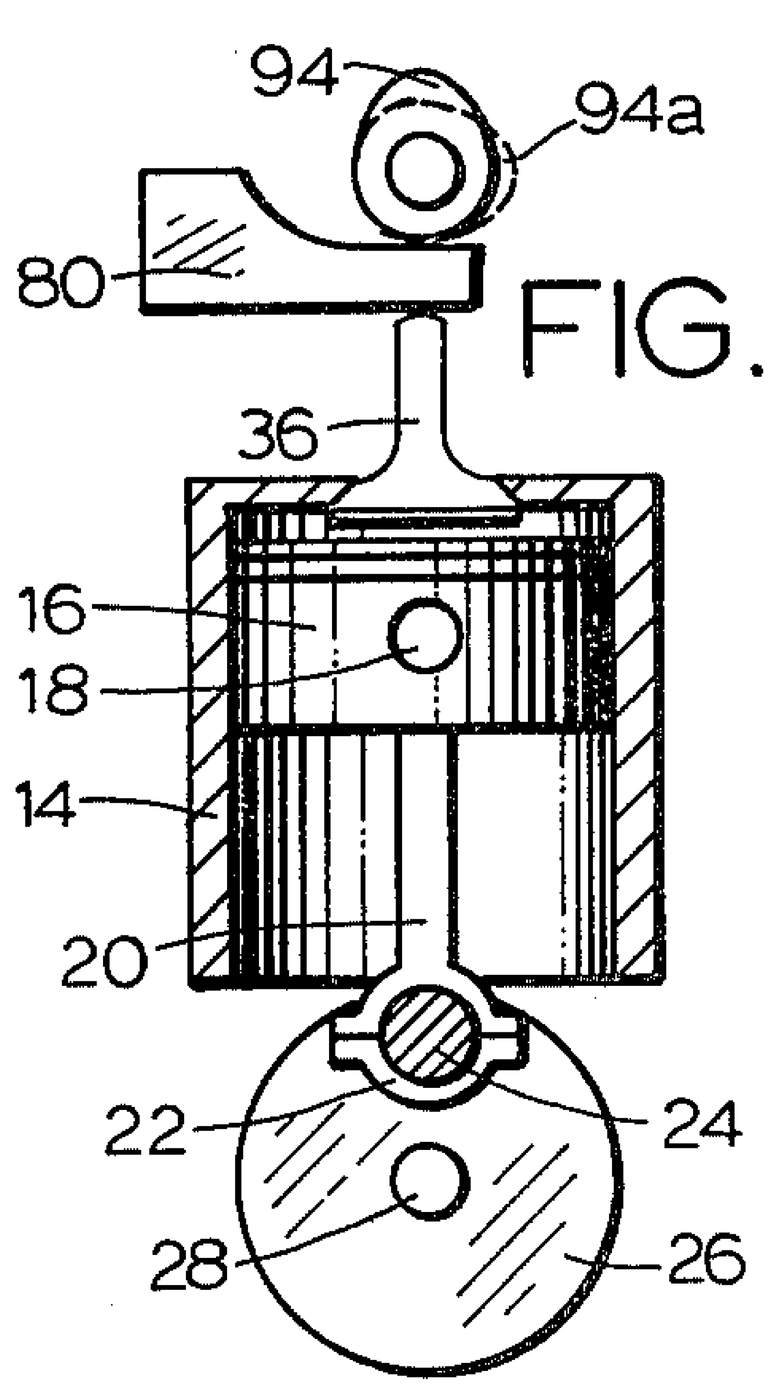

FIG. 9

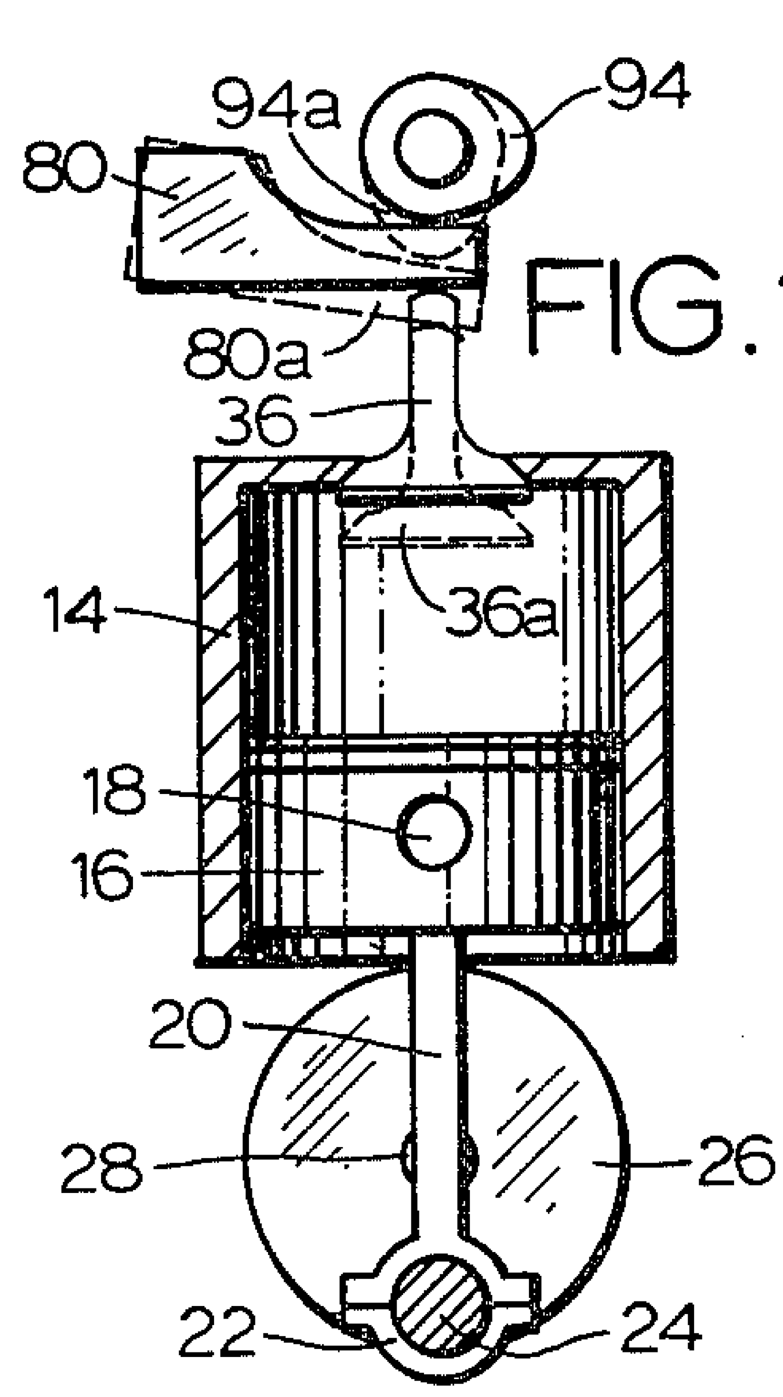

FIG. 10

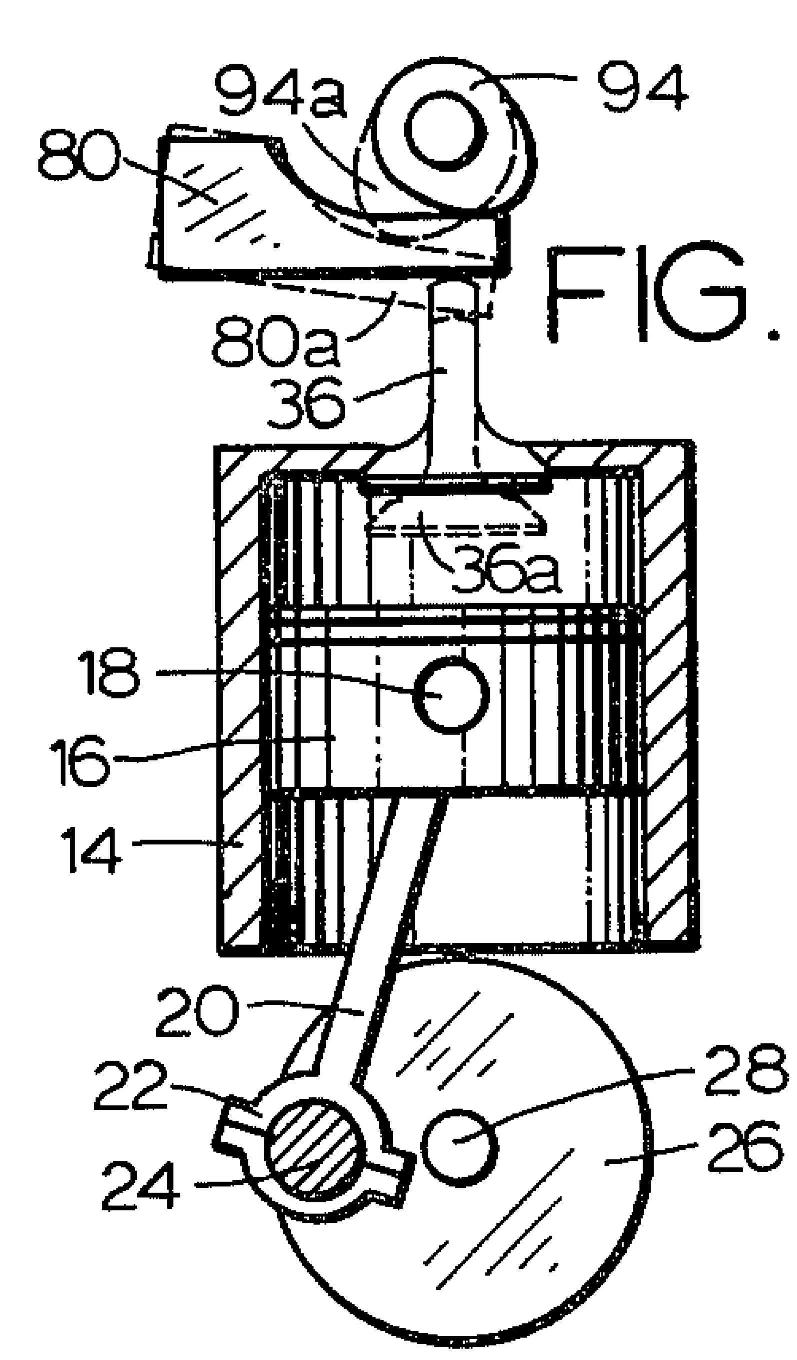

FIG. 11

APPARATUS AND METHOD FOR CONTROLLING THE VALVE OPERATION OF AN INTERNAL COMBUSTION ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

My copending application titled "Variable Valve Operating Mechanism for Internal Combustion Engines", Ser. No. 310,655, filed on Oct. 13, 1981, now U.S. Pat. No. 4,414,931, contains subject matter related to this application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to internal combustion engines, and pertains more particularly to apparatus for determining the time the valves open and close, as well as the amount of lift and the duration of valve opening.

2. Description of the Prior Art

A relatively large number of mechanisms have been devised for controlling the opening and closing of inlet and exhaust valves for internal combustion engines. In this regard, some are quite simple, but perform only one function, such as controlling the height of valve opening, frequently referred to as the valve lift. Others have controlled the period or duration of valve opening without varying the lift.

One relatively early patent which depicts a mechanism for adjusting only the valve lift is U.S. Pat. No. 1,395,851, issued Nov. 1, 1921, to Francis B. McLean for "Valve Operating Mechanism". The effective moment arm or leverage for affecting the opening of the valve is derived from a rocker arm that is pivotally mounted intermediate its ends, the fulcrum or pivot point being shiftable in order to vary the amount of valve lift produced by the valve cam.

A patent depicting a mechanism that determines both the amount of valve lift and the time that the valve remains open is found in U.S. Pat. No. 2,412,457, issued on Dec. 10, 1946 to Laurence D. Harrison for "Valve Actuating Mechanism". The mechanism employs a profiled or contoured adjusting lever or rocker arm that is shifted relative to the valve to be opened and closed. However, the control of the lift and duration are integrated with each other and one cannot be realized in practice without affecting the other. Here again, the predominant change is in the duration, the correlated change in lift being quite minimal.

For the most part, prior art devices for varying the valve lift are indeed quite complicated and relatively costly. Furthermore, some of the devices with which I am acquainted contain parts that are vulnerable to wear with the consequence that their lift span is unduly short. In such instances, the owner would be confronted with the likelihood of frequent and costly repairs, thereby militating against the adoption of such valve actuating mechanisms.

SUMMARY OF THE INVENTION

It is an object of my invention to provide apparatus that will progressively cause a desired change in valve lift followed by a desired change in the duration that the valve is open.

Another object of the invention is to control the valve timing so that the valves open earlier or later, as well as closing earlier or later, depending upon load

conditions to which the internal combustion engine is subjected.

A more specific object of the invention is to increase the valve lift to a practical maximum before increasing the duration or period that the valve remains open. A further object of my invention is to provide apparatus for operating internal combustion engine valves that will reliably change the valve opening and closing sequence from a fuel efficient (thermally efficient) cruise or normal operating mode to a mechanically efficient (volumetrically efficient) operating mode, doing so rapidly. Hence, it is an aim of the invention to enable the vehicle to travel under cruise conditions, where the load requirements are relatively light, and to effect a change rapidly when the load to which the engine is subjected requires a substantial increase, such as when undergoing acceleration or during other abnormal load situations.

A further object of the invention is to make substantial use of conventional parts. In this regard, the valve arrangement normally utilized in connection with internal combustion engines can remain unchanged. Even the camshaft and the cams thereon can be of conventional types. However, it is an aim of the invention to shift the camshaft in a linear direction so that the cams thereon bear against working or cam follower surfaces on rocker arms that follow the valve lift and valve duration in accordance with the shifted position of the camshaft at any given moment.

Still another object of the invention is to provide apparatus for controlling the opening and closing of internal combustion engine valves that will be rugged, longlasting and require little maintenance.

Still further, an object of the invention is to provide variable valve operating apparatus that can be used in combination with conventional sensing devices. In this regard, my invention lends itself readily to being controlled by a conventional vacuum device, such as a diaphragm connected to the intake manifold of the internal combustion engine, and to a speed-responsive device such as a governor that is driven in accordance with the engine's speed.

It is also an object of the invention to control the valve opening and closing pattern in such a manner that the intake valve is closed early or later during the intake stroke of the piston, thereby causing a lesser charge or mixture of fuel and air to be inducted into the cylinders or combustion chambers when the engine is subjected to light loads, yet permitting the amount of fuel and air to be increased when load conditions increase. Stated somewhat differently, an aim of the invention is to provide what might be termed a five cycle operation of an internal combustion engine in contradistinction to the more common four cycle operation. More specifically, it is planned that the five cycle operation will consist of a variable intake stroke, a variable expansion stroke (which continues for the remainder of the period that would normally constitute the intake stroke), a compression stroke, a power stroke and an exhaust stroke.

For a general object, it can be stated that my invention enables a number of controls to be exercised with respect to the opening and closing of the valves of internal combustion engines, whether they be inlet or exhaust valves, and which will also provide a control of the time at which the valves begin to open and the time that they close. Also, the amount of charge taken into each cylinder of the internal combustion engine can be controlled so as to induce a smaller charge to enter the cylinders when the engine is operating under light loads, yet causing a much greater charge to be drawn into the cylinders when power requirements increase.

Briefly, my invention makes use of a camshaft that is rotatable about a laterally shiftable axis. The cams on the camshaft bear against rocker arms having cam surfaces configured so as to change the valve lift during the initial lateral movement of the camshaft in one direction and to change the duration that the valves are open when additional movement in the same lateral direction is imparted to the camshaft. This is accomplished by using a rocker arm for each valve to be actuated. The rocker arm has a working or cam follower surface thereon which includes a straight section and a curved section. By laterally shifting the camshaft so that each cam thereon bears against the straight section, only the amount of valve lift is changed, yet when the camshaft is moved sufficiently farther so that the cams thereon bear against the curved section of the working surface, the duration or time that the valves are open is increased. The moment at which the valves start to open, and the moment at which they close, can be adjusted or indexed independently of the lateral position of the camshaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of an internal combustion engine in block form utilizing my valve controlling apparatus and timing;

FIG. 2 is a top plan view corresponding to FIG. 1 but without the valve cover thereon and without the timing mechanism included;

FIG. 3 is a greatly enlarged sectional view taken in the direction of the irregular line 3—3 of FIG. 2, the view showing the camshaft in one position and with the inlet valve actuated thereby closed;

FIG. 4 is a view corresponding to FIG. 3 but with the camshaft shifted and the valve open;

FIG. 5 is a sectional view of one of the cylinders contained in the engine of FIG. 1 with the open inlet valve shown in solid outline and the closed exhaust valve shown in phantom outline, the view depicting the beginning of an intake stroke;

FIG. 6 shows the piston of FIG. 5 descending but with both valves closed;

FIG. 6A is a view corresponding to FIG. 6 but with the exhaust valve still closed and the inlet valve still open instead of being closed as in FIG. 6 in order to permit a greater charge of fuel and air to be drawn into the cylinder than that inducted in FIG. 6;

FIG. 7 is a view showing the piston after it has moved to bottom dead center from the intermediate position of FIG. 6, but valves now being closed;

FIG. 7A shows the completion of the piston movement of FIG. 6A, the exhaust valve remaining closed and the inlet valve about to close;

FIG. 8 depicts the compression stroke in progress, both valves being closed;

FIG. 9 depicts the completion of the compression stroke and the beginning of the power stroke, both valves still being closed at this time;

FIG. 10 shows the ending of the power stroke and the beginning of the exhaust stroke, the phantom exhaust valve being open, and

FIG. 11 shows the exhaust stroke in progress, the exhaust valve still being open.

DESCRIPTION OF THE PREFERRED EMBODIMENT

It will be observed from the drawings that a conventional internal combustion engine **10** has been shown in a highly diagrammatic form in FIG. **1**. As better appreciated from FIGS. **3** and **4**, the engine **10** comprises a cylinder block **12** containing a combustion chamber **14** therein, the chamber **14** being one of any number of such cylinders. Overlying the cylinder block **12** and secured thereto is a cylinder head **15**.

As can be learned from FIG. **2**, the combustion chamber **14** constitutes one of four such combustion chambers or cylinders. The combustion chamber or cylinder **14** that appears fragmentarily in FIGS. **3** and **4** has also been shown in FIGS. **5**, **6**, **6A**, **7**, **7A** and **8-11**, together with a piston **16** reciprocably movable within the cylinder **14**.

Although more will be said with respect to FIGS. **5-11** when considering the manner in which my invention permits the engine **10** to be operated, it will be well at this stage to refer to the piston labeled **16** and the means via which it is vertically reciprocated within the combustion chamber or cylinder **14**. In this regard, a wrist pin **18** connects the piston **16** to the upper end of a connecting rod **20** that has a bearing **22** at its lower end which encircles a crankpin **24** that is eccentrically mounted on a crankarm in the form of an eccentric **26** in the illustrative situation, the crankarm or eccentric **26** being mounted on a crankshaft denoted by the reference numeral **28**. The piston **16** and the parts **18-28** subjacent thereto are of conventional construction, being common to all internal combustion engines. It is the manner in which my valve operating apparatus coacts in a timed relation with the movement of the piston **16** that is important and which will hereinafter be discussed in detail.

From FIGS. **3** and **4**, it will be discerned that there is a valve port **30** formed by a downwardly facing beveled seat **32**. For the sake of simplicity, it will be considered that the valve port **30** constitutes an intake opening. Therefore, a passage **34** extends to the opening or port **30** from the intake manifold (not shown) of the engine **10** to supply a charge or mixture of fuel and air to the cylinder **14**.

Also, conventionally included is a valve **36** having a valve head **38** at its lower end, the valve head **38** being beveled at **40** so as to seat against the beveled seat **32**. Extending upwardly from the head **38** is a stem **42**. Formed in the upper end portion of the stem **42** is an annular groove at **44** for anchoring a washer-like retainer **46**. A coil spring **48** acts against the retainer **46** to normally close the valve **36**. It should perhaps be mentioned that the inlet valve **36** of FIGS. **3** and **4** also appear in FIGS. **5-11** and that the exhaust valve labeled **36*a*** also appears in FIGS. **5-11**, being shown in phantom outline to distinguish it from the inlet valve **36** which is illustrated in solid outline. It might be well to label the retainers on the exhaust valves **36*a*** (not visible in FIG. **2**) as **46*a*** so as to denote the locations, in a general way, of the valves **36*a***.

It should be made clear at this time that the foregoing description has dealt with parts of a conventional internal combustion engine **10**. Because of this, it has not been necessary to go into any great detail, resort having been made to showing the parts in a highly diagrammatic form.

Turning now to a description of parts that coact with the conventional parts that have been described, and which parts comprise my invention, it will be pointed out that the valve operating apparatus selected to exemplify my invention has been indicated generally by the reference numeral **50**. The apparatus **50** includes a valve housing denoted in its entirety by the reference numeral **52**. The valve housing **52** includes side walls **54** and end walls **56**. The side walls **54** are formed with hold-down feet **58** which are anchored to the cylinder head **15** by means of bolts **60**. A specially configured lid **62** is held in place by bolts **64** which extend downwardly into tapped holes **66** in the side walls **54**, the tapped holes **66** being visible in FIG. **2**; in this regard, the lid **62** has been removed in FIG. **2** in order to show parts of my apparatus **50** that would otherwise be concealed. The specially configured lid **62** has a groove **68** extending partially across its underside, the groove **68** performing a guiding function presently to be made clear. At this time, it will be pointed out that the groove **68** may have one or more ribs **70** therein so as to assist in the guiding action yet to be described.

Secured to the inner face of the left side wall **54**, as viewed in FIGS. **3** and **4**, is a support block **72**. The support block **72** may be secured to the inner face of the left wall **54** by bolts or by welding, neither of which is illustrated. Extending upwardly from the block **72** are a pair of upstanding ears **74**, there being two such ears **74** for each valve **36**, **36***a* to be actuated. A tubular shaft **76** extends through all of the upstanding ears **74**, (see FIG. **2**) the shaft **76** having a radially directed oil hole **78**. In practice, it is intended that one end of the tubular shaft **76** be connected to an oil supply (not shown) so that oil can be delivered therethrough for lubricating purposes presently to be explained.

There is a rocker arm **80** for each inlet valve **36** and a rocker arm **80***a* for each exhaust valve **36***a*. The rocker arms **80** and **80***a* need not be identical, although they are similar. Of course, each rocker arm **80** would be a replica of the other, as would each rocker arm **80***a*.

With respect to the rocker arm **80**, as shown in FIGS. **3** and **4**, it can be seen that one end **82** thereof is pivotally mounted on the previously mentioned tubular shaft **76**. The other end **84**, which is the free end, acts against the upper end of the valve stem **42**. In practice, a pad (not shown) can be pivotally carried or mounted to the free end **84** so as to bear against the upper end of the valve stem **42**. However, an exemplary pad arrangement is depicted in my copending application titled "Variable Valve Operating Mechanism for Internal Combustion Engines", herein identified as a related application.

The upper side of each rocker arm **80**, and also the upper side of each rocker arm **80***a*, is formed with a working or cam follower surface denoted generally by the numeral **86**. More specifically, the contact surface **86** includes a straight section **88** and an upwardly curving or non-linear section **90**, the section **90** having an oil hole **92** formed therein which communicates with the oil hole **78** in the tubular shaft **76**. Thus, when oil under pressure is forced through the tubular shaft **76**, some of the oil is discharged through the oil holes **78** and **92** onto the upwardly curving section **90** of the working surface **86**. For the sake of drafting simplicity, the surface **86** has not been shown as having a channeled or grooved cross section. However, it is preferred that the entire contact or working surface **86** be channeled or grooved in actual practice, such as that shown in my copending application, supra.

Although the camshaft is basically of conventional construction, the manner in which it is mounted is believed to be unique. First, though, it should be explained that the camshaft, identified generally by the reference numeral **93** carries thereon a number of cams **94**, **94***a*, there being one such cam **94** for each inlet valve **36** and a cam **94***a* for each exhaust valve **36***a* to be actuated. From FIG. **2**, since there are four cylinders **14**, and hence four rocker arms **80** and four rocker arms **80***a*, there will be a total of eight cams (four labeled **94** and four labeled **94***a*). One cam **94** appears in FIGS. **3** and **4**. It will be observed that it has a circular base portion **96** and a lobe portion **98**. The profile or edge of the cam **94**, composed of the portions **96** and **98**, bears against the working surface **86**, composed of the follower sections **88** and **90**, formed on the upper side of the rocker arm **80**. Depending upon the position of the camshaft **93**, the cam profile **96**, **98** will bear against the straight section **88** or the upwardly curved section **90**.

Describing now the manner in which the camshaft **93** is mounted so that its axis of rotation can be shifted in order to cause the cam **94** to bear against selected portions of the working or contact surface **86** formed on the upper side of the rocker arm **80**, it will be perceived from FIG. **2** that there are five shafts indicated generally by the reference numeral **100**. The number of shafts **100** is susceptible to variation. What is required is that the entire camshaft **93**, that is throughout its complete length, be shifted laterally in a manner so that its axis of rotation remains parallel to the pivotal axis provided by the tubular shaft **76** for the rocker arms **80**, **80***a*.

Although the line **3**—**3** in which FIG. **3** is taken as far as FIG. **2** is concerned is irregular, it aptly pictures the valve actuation that is produced when employing my invention; the directional line **3**—**3** in FIG. **2** produces FIG. **4**, as well as FIG. **3**. With this in mind, it will be noted from FIGS. **3** and **4** that the shaft **100** there appearing has a central or intermediate threaded section **102** and two unthreaded sections **104**, **106**. The unthreaded sections **104**, **106** are journaled for rotation in sleeve bearings **108** mounted in the side walls **54**. The threaded section **102** extends through a block **110** having a threaded bore **112**. Since there are five shafts **100**, there are five blocks **110**. Each block **110** forms one bearing for the camshaft **93**. In this regard, each block **110** has a retention plate **114** secured to its underside by reason of holding bolts **116** that extend upwardly into the block **110** in each instance. Although not shown, it will be appreciated that the bearings that journal the camshaft can be split sleeve bearings, one-half residing in the lower portion of the block **110** that has a semicircular recess and the other half residing in a semicircular recess in the retention plate **114**.

The groove **68** in the underside of the lid **62** has already been briefly mentioned. It should be clear, though, that the groove **68** guides the block **110** laterally back and forth. When a rib **70** is used, then the upper face of the block **110** would be correspondingly grooved to accommodate such a rib **70** (or ribs **70**). In other words, the block **110** is constrained to move transversely or laterally depending upon the direction in which its shaft **100** is rotated.

The unthreaded sections **104**, **106** of each shaft **100** are journaled for rotation in sleeve bearings **118**, there being one contained in each side wall **54**. From FIG. **2**, it will be perceived that each shaft **100** has a sprocket

120 thereon. The various sprockets **120**, and there are five in the exemplary situation, are driven through the agency of a chain **122** entrained about a drive sprocket **124** that is on the shaft **126** of an electric motor **128** at one end of the engine **10**. All that need be appreciated at this time is that when the motor **128** is energized for operation in one rotative direction, the threaded section **102** of each of the shafts **100** will cause its block **110** to be moved transversely or laterally from the position depicted in FIG. **3** to that pictured in FIG. **4**. Of course, any position therebetween can also be realized.

Inasmuch as vacuum-responsive devices, speed-responsive devices, and microprocessors utilized in conjunction with internal combustion engines are well-known, no need exists for detailing the construction of such devices when employed in conjunction with my apparatus. Since the apparatus is intended to be automatically controlled, in accordance with the vacuum prevailing at any given moment in the intake manifold (where my invention is used for controlling an inlet valve **36**), a vacuum device **132** has been illustrated in block form, being connected to the intake manifold (not shown) of the engine **10**. It can be a simple diaphragm device. Also, a speed-responsive device **130** operates in accordance with the speed of the engine **10**, the camshaft **93** also being driven in accordance with the speed of the engine **10** as will become manifest hereinafter.

Extending between the vacuum device **132** and the speed-responsive device **130** is a control rod **134** having an arm **136** attached thereto so that the arm **136** moves to the left or right in unison with the control rod **134**. When the arm **136** moves sufficiently to the left, it engages a switch **138** in circuit with the motor **128** which causes the shafts **100** to be rotated in a direction to shift the blocks **110** from the position in which they are shown in FIG. **2** (and FIG. **3**) to the position in which one appears in FIG. **3**. Conversely, when the control rod **134** is moved to the right, a switch **140** is engaged which energizes the motor **128** to cause rotation thereof in an opposite direction, thereby returning the blocks **110** from the position in which one appears in FIG. **4** to that in which it appears in FIG. **3** (and which the five blocks **110** appear in FIG. **2**). The foregoing operation, in a sense, can be likened to that of a power window which conventionally can be moved into various positions, any one of which is firmly and unyieldingly maintained until the motor is energized to change the window position.

Once again, it should be taken into consideration that various intermediate positions of each block **110** can be established so that there is virtually an indeterminate number of adjusted positions that the cam shaft **93** can be shifted into.

At this stage, it is to be appreciated that when the control rod **134** is moved a sufficient distance to the left, then the cam **94** shown in FIG. **3** rides against the curved section **90** of the working surface **86** to cause the rocker arm **80** to be forced downwardly for a longer period during each rotation of the camshaft **93**, because engagement between the cam **94** and the curved section **90** is maintained for a longer period of time than when the cam **94** engages the straight section **88**. Consequently, the valve **36** will be open for a longer period of time; not only that, but its lift or downward travel will be increased by reason of the increased moment arm existing under this circumstance by virtue of the end **84** of the rocker arm **80** being actuated through a greater distance.

Stated somewhat differently, when the motor **128** causes the blocks **110**, and also each rocker arm **80** (and **80*a***) mounted thereon, to move to the position appearing in FIG. **4**, the increased opening, both as to the lift of the valve member **36** (and **36*a***) and the duration and or time in which it is maintained open is increased. Hence, the charge of mixed fuel and air that is introduced via the passage **34**, and there would be one such passage **34** for each inlet valve **36**, is increased and the engine **10** is supplied with more fuel for the increased load condition. This condition would be experienced in practice during, say, the acceleration of a vehicle having an engine **10** equipped with my adjusting apparatus **50**.

On the other hand, when the adjusting apparatus **50** is in the relationship appearing in FIG. **3**, that is with the block **110** toward the right, the valve member **36** is not opened as long because the cam lobe **98** of the cam **94** engages only the straight section **88**. Hence, a lesser amount or charge of mixed fuel and air enters the combustion chamber **14** under this condition. This condition enhances the normal operation of the engine **10**, such as when the vehicle is cruising. As already indicated, there are various intermediate positions that can be established for the camshaft **93**, all depending upon the operating load conditions experienced at any given moment by the engine **10**.

My invention permits a versatile construction and operation of the valves and the timing thereof, as will soon be described. At this point, though, it will be well to stress that the rocker arms **80** and **80*a*** need not be replicas of each other. The working or follower surface **86** of the rocker arm **80*a***, although not illustrated as differing, may have a different profile from that constituting the working surface **86**, the profile of which has been shown for the rocker arm **80**. In this regard, it will be understood that the length of the straight section **88** on the rocker arms **80*a*** may be of a different length from the section **88** on the rocker arms **80**; likewise, the configurative profile of the sections **88** and **90**, as shown, is susceptible to variation in order to adapt the rocker arm **80** to the valve requirements of the particular engine **10** with which my apparatus is to be incorporated. The foregoing is especially pertinent to the description of FIGS. **5–11**, hereinafter presented.

From FIGS. **1** and **2**, it will be observed that the camshaft **93** has a timing gear **142** thereon (shown as a pulley in FIG. **1**). As can be seen from FIG. **1**, the crankshaft, only an end of which is shown, has a timing gear **144** thereon (shown only in FIG. **1** and depicted as a pulley). Inasmuch as the camshaft **93** is to rotate at half the speed of the crankshaft **28**, as is customary, the gear **142** would have twice as many teeth as the gear **144**. Although teeth are not shown in FIG. **1**, an effort has been made to illustrate the reduction by reason of the different diameters of the elements **142, 144**.

Although the timing gears **142, 144** (or sprockets or pulleys) are conventional, it is believed that my timing mechanism denoted generally by the reference numeral **150** is novel. Although the belt indicated by the numeral **152** could be a chain, the drawing is simplified somewhat by showing a belt (and the members **142, 144** as pulleys).

The timing mechanism **150**, as exemplified in FIG. **1**, includes the timing belt **152** that is only diagrammatically shown. It will be noted, however, that the belt **152** passes about the upper timing gear or pulley **142** on the camshaft **93**, the gear being shown as simply a pulley for drafting simplicity as already indicated, and also about the timing gear or pulley **144** on the crankshaft **28**, the crankshaft gear **144** also being shown merely as a pulley. In order to take up any slack, an idler pulley **154** (a gear or sprocket in practice) is at the left, being rotatably carried at the upper ends of a pair of pivotal arms **156**, there being a pin **158** that rotatably journals the pulley **154**. The lower ends of the arms **156** are pivotally mounted with respect to the cylinder block **12** of the engine **10** by virtue of a pivot pin **160**.

Made use of in effecting an adjustment in the timing, the camshaft **93** has a stub portion **93***a* projecting beyond the face of the gear or pulley **142**. The stub portion **93***a* has a sleeve bearing **162** encircling same. Secured to the sleeve bearing **162** and projecting radially therefrom in a horizontal direction is a rod **164** that has an electric motor **166** attached thereto. The electric motor **166** has a shaft **168** projecting from the end thereof opposite from the end attached to the rod **164**, the shaft **168** having a threaded end portion **170** received in tapped hole **172** extending diametrically through a cylindrical boss **174** that is pivotally attached to one side of a vertical arm **176**, the boss **174** being mounted intermediately the ends of this arm **176** at **178**, such as by means of a shoulder bolt (not visible) extending through a hole (not visible) in the arm **176** from the far side thereof into the boss **174**. The lower end of the vertical arm **176** is pivotally mounted to the cylinder block **12** of the engine **10** by means of a pivot pin **180** and a tubular spacer **182**. The upper end of the arm **176** carries an adjusting pulley **184** that is rotatably mounted on a pin **186** projecting from the opposite side of the vertical arm **176** from that which the boss **174** projects.

It should be obvious from FIG. **1** that when the motor **166** is energized so as to rotate the threaded shaft **168** in one direction, the arm **176** is swung about its pivot pin **180** in either a clockwise or counterclockwise direction. When swung in a clockwise direction, it is apparent that the gear or pulley **142** on the camshaft **93** is angularly shifted in a clockwise direction with respect to the gear or pulley **144** on the crankshaft **28**, thereby retarding the valve action with respect to the crankshaft **28**, which is rotating in a counterclockwise direction, as is conventional. When the motor **166** is energized to cause its shaft **168** to rotate in an opposite direction, then the arm **176** is rocked in a counterclockwise direction to advance the timing action.

In a number of instances one would rely solely on the shifting of the camshaft **93** to change the valve timing. To do this a fixed pin **93***b* attached to the cylinder block **12** would be used with the sleeve bearing **162** placed on the fixed pin **93***b*. This would fixedly locate the pulley **184** so that the valve timing would be automatically changed as the camshaft **93** is shifted by the motor **128**.

Having presented the foregoing description, it will now be easier to understand the method illustrated in FIGS. **5–11**. The applicant can think of no better succinct term than "five-cycle" operation in contradistinction to the usual "four-cycle" operation. It is important, however, to recognize that my invention permits an engine equipped with my valve operating mechanism to be operated in the so-called "four-cycle" mode, as well as the "five-cycle" mode, depending upon the load to which the engine **10** is subjected at any given time. More specifically, my method enables the five-cycle operation to become effective during lighter load conditions and progressively continuing toward a four-cycle operational mode when a full load engine operation is required. Stated somewhat differently, a lesser charge of fuel and air enters each cylinder or combustion chamber **14** of the engine **10** during the five-cycle operation, the amount of inducted charge increasing progressively to accommodate for the increasing load on the engine, the five-cycle operation changing completely to the conventional four-cycle when full load is reached.

Before describing FIGS. **5–11** in detail, it can be explained that the five-cycle mode may be described as including the following sequence: (1) intake, (2) expansion, (3) compression, (4) power, and (5) exhaust in contrast to the usual: (1) intake, (2) compression, (3) power, and (4) exhaust for conventionally designed valve mechanisms. It will also be beneficial to point out that, in practice, intake and exhaust valves do not open and close precisely at the top and bottom dead center positions. The reasons for this are well understood. Typically, inlet valves open 7 degrees or so prior to the piston reaching top dead center preparatory to the beginning of the customary intake stroke, closing perhaps 45 degrees after bottom dead center on the compression stroke. Exhaust valves on the other hand, may well open 50 degrees before bottom dead center of the piston or the power stroke, remaining open during the exhaust stroke, and finally closing, say, 9 degrees after top dead center on the usual intake stroke. The valve overlap can be on the order of 16 degrees with respect to the opening of intake valves prior to the closing of the exhaust valves on an internal combustion engine. Angle values, such as those alluded to above, may be realized with my invention, certain of them being controlled so as to improve the fuel efficiency of an internal combustion engine when equipped with my apparatus **50**. It will facilitate the ensuing description, however, to consider the opening and closing of the inlet and exhaust valve **36** and **36***a*, respectively, as coincidently occurring at top and bottom dead center positions of the piston **16**.

Referring now to FIG. **5**, and remembering that the valve **36**, shown in solid outline, represents an inlet valve, and that the valve **36***a*, shown in phantom outline, represents an exhaust valve, the top dead center position of FIG. **5** depicts the start of an intake stroke, the inlet valve **36** being open and the outlet valve **36***a* being closed.

FIG. **6** shows the ending of the inlet stroke begun in FIG. **5**, and the initiation of the expansion stroke available when practicing my invention. It will be perceived that both valves **36**, **36***a* are now closed and that the camshaft **93** remains in the same lateral position as in FIG. **5**. It should be evident that the piston **14**, having moved only partway down in the cylinder **14** has drawn in a lesser charge of fuel and air than had the piston **16** traveled the full vertical length of the cylinder **16** with the inlet valve **36** open during such full travel of the piston **16**, that is, from its top dead center position to its bottom dead center position. The lesser charge would be required under light load conditions, and hence the desirability of effecting the early closing of the inlet valve **36** as illustrated in FIG. **6**.

A greater charge would be required under heavier loads, particularly full load, and the capability of supplying more fuel and air when so needed is portrayed in FIG. **6A** (and FIG. **7A**). In FIG. **6A** it is to be observed that the inlet valve **36** is still open, this being by virtue of the camshaft **93** having been shifted to the left in this figure from the position shown in FIG. **6** (and FIG. **5**).

Consequently, when the piston **16** continues downwardly from the intermediate position of FIG. **6** to the bottom dead center position shown in FIG. **7**, no more fuel/air is inducted into the cylinder **14**, for the inlet valve **36** remains closed during this period. This is what has been termed the "expansion" stroke because the mixture that has been drawn in experiences a vacuum or subatmospheric pressure during this latter portion of the downward travel of the piston **16**. By contrast, though, the travel of the piston **16** from its intermediate position appearing in FIG. **6**A to its bottom dead center position of FIG. 7A, draws in a full charge of fuel and air, for the camshaft **93** remains in its leftward position and the cam **94** keeps the valve **36** open by engaging the curved section **90**, whereas in FIGS. **5**, **6** and **7** only the straight section **88** is engaged.

Obviously, the camshaft **93** can be shifted to positions in between those shown in FIGS. **5**, **6**, **7**, and those shown in FIGS. **6**A, **7**A, thereby accommodating a range of load conditions. As an example, the inlet valve **36** could be kept open until the piston **16** had completed 75% of its downward travel rather than the 50% shown in FIG. **6** (and FIG. **6**A). In other words the camshaft **93** is adjustably shifted to open and close the inlet valve **36** at the best time in order to effect an optimum, and hence more efficient, supply of fuel and air to the cylinder **14**. Thus, with my invention the intake stroke is varied to suit the load conditions at any given time; by the same token the decompression stroke is correspondingly varied. One is increased as the other is decreased, all as the piston **16** moves from top dead center to bottom dead center.

Once bottom dead center is reached, as illustrated in FIGS. **7** and **7**A, the piston **16** starts to move upwardly, thereby initiating the compression stroke occurring in FIG. **8**. Of course, both valves **36**, **36***a* are closed during this upward movement of the piston **16**. The compression stroke is completed when the piston **16** again reaches top dead center, as illustrated in FIG. **9**. FIG. **9** also represents the start of the power stroke with FIG. **10** depicting the completion of the power stroke and FIG. **11** shows the piston **16** in the process of again moving upwardly, this being during the exhaust stroke with the valve **36***a* open. It is not deemed necessary to depict the camshaft position of FIGS. **6**A and **7**A as it would appear when corresponding to FIGS. **5**, **8**, **9**, **10** and **11**; the cam **94** would still be engaging the straight section **88** and the valve **36** would be actuated very similarly as in these FIGS. **5**, **8**, **9**, **10** and **11**, but only with an increased lift.

Recapitulating for a moment it might be well to point out that the sum of the intake and decompression stroke corresponds to the conventional intake stroke, as customarily considered when describing the operation of the usual four-cycle engine. My compression, power and exhaust strokes correspond to those of a four-cycle engine. It is the ability to shift in a relative manner the camshaft **93** with respect to the rocker arm **80** that enables the five-cycle method constituting my invention to be realized. Consequently, under light loads the camshaft **93** would remain in the position in which it is illustrated in FIGS. **5**, **6**, **7**, **8**, **9**, **10** and **11**, whereas under a heavier or full load, the camshaft would first be shifted to the left, as shown in FIGS. **6**A and **7**A, remaining in this shifted position as long as the increased or full load continues.

I claim:

1. A timing mechanism for internal combustion engines having a camshaft, a timing gear member mounted on said camshaft, a crankshaft and a timing gear member mounted on said crankshaft, and endless belt means entrained about said timing gear members, said mechanism comprising means for directing a portion of said endless belt means in a direction generally perpendicular to a line extending between said camshaft and said crankshaft, said directing means including an additional gear member and said endless belt means being entrained about said timing gear members and said additional gear member, threaded means for shifting said directing means to effect a differential angular movement between said timing gear members, idler means for maintaining said endless belt means taut as said additional gear member is shifted, a pivotal arm, said additional gear member being mounted at one end of said pivotal arm, means mounting the other end of said arm for pivotal movement, means engaging an intermediate portion of said pivotal arm for effecting angular movement of said arm to produce said differential angular movement of said timing gear members, said means for angularly pivoting said arm including a motor, a threaded shaft drive extending from one end of said motor, said arm having a member thereon for threadedly receiving a portion of said threaded shaft so that said threaded shaft when rotated by its motor will cause said arm to be pivotally moved, a rod fixedly connected at one end to the other end of said motor, and a bearing encircling a portion of said camshaft, the other end of said rod being connected to said bearing.

2. Apparatus for operating a valve of an internal combustion engine having a reciprocable valve member for opening and closing a valve port in communication with a combustion chamber of the engine, the apparatus comprising a rocker arm, means mounting one end of said rocker arm for pivotal movement about a fixed axis so that the other end of said rocker arm acts against said valve member, a camshaft, a cam on said camshaft engageable with said rocker arm, and means for shifting said camshaft relative to said fixed axis so that said cam is engageable with various longitudinal portions of said rocker arm between its said other end and its said one end, said shifting means including bearing means for rotatably supporting said camshaft and means threadedly engaging said bearing means for moving said bearing means to effect said shifting of said camshaft relative to said axis.

3. Apparatus in accordance with claim **2** in which said rocker arm has a straignt section extending from its said other end toward its said one end to provide at least some of said various longitudinal portions of said rocker arm.

4. Apparatus in accordance with claim **3** in which said rocker arm has a curved section extending from its said one end toward its said other end to provide at least some of said various longitudinal portions of said rocker arm.

5. Apparatus in accordance with claim **3** in which said rocker arm has a working surface against which said cam bears, said working surface including a straight section extending partway from its said other end toward its said one end and said working surface including a curved section extending from said one end of said rocker arm to said straight section.

6. Apparatus in accordance with claim **5** including a shaft, said shaft providing said fixed axis.

7. Apparatus in accordance with claim **6** in which said shaft is tubular.

8. Apparatus in accordance with claim **7** including additional rocker arms, each being mounted at one end for pivotal movement about said tubular shaft, said camshaft having a cam for each of said rocker arms, so that when said camshaft is shifted, the cams thereon are correspondingly shifted relative to said tubular shaft and relative to all of said rocker arms.

9. Apparatus in accordance with claim **2** including means for journaling said threaded shaft for rotation about an axis perpendicular to said rocker arm axis.

10. Apparatus in accordance with claim **9** in which one end of said threaded shaft has a pulley thereon, and means for rotating said pulley in accordance with the load to which the internal combustion engine is subjected.

11. Apparatus in accordance with claim **10** including a piston reciprocably disposed in said combustion chamber, a crankshaft for reciprocably moving said piston within said chamber, and means for effecting an angular shifting of said camshaft in relation to said crankshaft so as to change the timing of said valve member with respect to the movement of said crankshaft and piston.

12. Apparatus in accordance with claim **11** including a timing pulley on said camshaft and a timing pulley on said crankshaft, endless belt means entrained about said timing pulleys, and an additional pulley in engagement with said endless belt means for directing a portion of said timing belt in a direction generally perpendicular to a line extending between the camshaft and said crankshaft, and means for shifting said additional pulley so as to effect a relative angular displacement between said timing pulleys and to effect the timing of said valve member with respect to the movement of said crankshaft and piston.

13. Apparatus in accordance with claim **12** in which said means for shifting said additional pulley includes an arm, said additional pulley being pivotally mounted at one end of said arm, means pivotally supporting the other end of said arm, and means for maintaining said arm in a substantially vertical relation.

14. Apparatus in accordance with claim **13** in which said means for shifting said additional pulley includes means for angularly moving said substantially vertical arm to shift said additional pulley and thus change said timing.

15. Apparatus in accordance with claim **14** in which said last-mentioned means includes a motor for changing the angular position of said arm.

16. Apparatus in accordance with claim **15** including a rod, a bearing encircling one end of said camshaft, one end of said rod being attached to said bearing and the other end of said rod being attached to said motor, said motor including a threaded drive shaft rotated by said motor, a member carried on said arm, said threaded shaft being threadedly engaged with said member on said arm, whereby the distance said threaded shaft is extended or retracted with respect to said motor will cause said arm to angularly move and thereby cause said additional pulley or gear to change said timing.

17. Apparatus in accordance with claim **16** including idler means for maintaining said endless belt means taut.

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